Introduction to Heating

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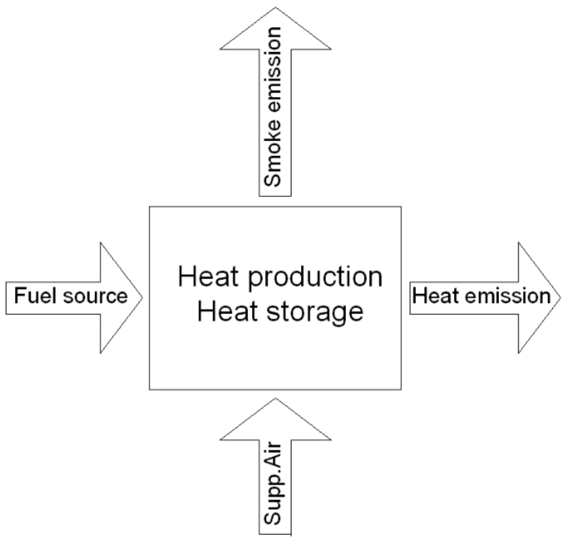
Classification of heating system according to the place of heat generation

- Local heating
- Central heating
- District heating

Local heating

The traditional and simplest way of satisfying the heat requirement of each space is to us a local or direct heating. The energy is brought to the space where the heat is needed and there converted to heat, which immediately or in a certain time delay (depends on the heat storage capacity of the equipment) emitted to the space. The heat-producing and emitting functions are combined in the same appliance.



Fuel sources and (some examples of equipments)

Fire wood
The use of wood as a fuel source for heating is as old as civilization itself. Historically, it was limited in use only by the distribution of technology required to make a spark. Wood heat is still common throughout much of the world.

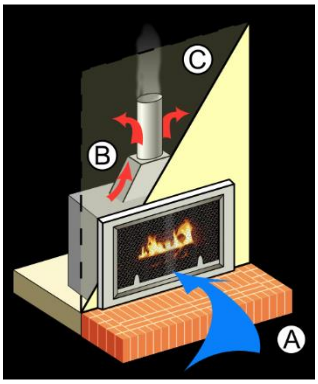
Early examples include the use of wood heat in tents. Fires were constructed on the ground, and a smoke hole in the top of the tent allowed the smoke to escape by convection.

The moisture content of firewood determines how it burns and how much heat is released. Unseasoned (green) wood moisture content varies by the species, green wood may weigh 70 to 100 percent more than seasoned wood due to water content. Typically, seasoned (dry) wood has between 25% to 20% moisture content.

Heat content of dry fire wood is 14-16 MJ/Kg

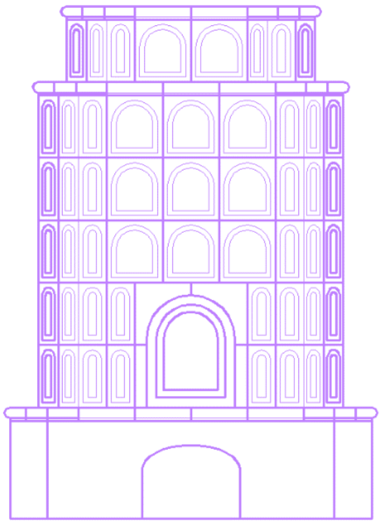
Equipments:

Open fireplace: The open fireplace, burning mainly wood, is more a decorative device satisfying an emotional need, than a heating appliance. In free air solid fuels burn at a temperature of only about 270°C, too low a temperature for perfect combustion reactions to occur, heat produced through convection is largely lost, smoke particles are evolved without being fully burned and the supply of combustion air cannot be readily controlled.

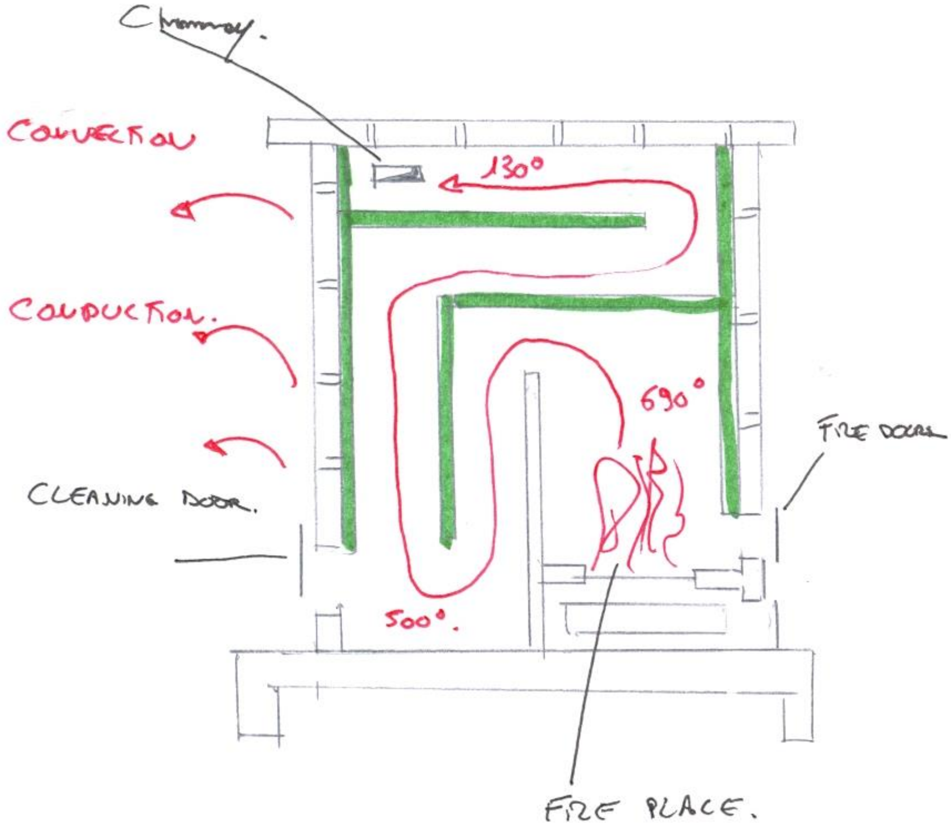


Closed fireplace: Manufactured ("prefab") fireplace with cast iron metal fire box existing wood framed or masonry chase with a chase cover. This type of fireplace is very popular for new construction for ease of installation and is very cost effective. This type of fireplace is currently being made for wood, biomass. It stores only a few amount of energy during wood burning, thus the produced heat emitted in to a place of it leaves through the chimney. The efficiency of it is relatively low.

Solid Fuel Stoves (tile-stove, kitchen-stove, cast-iron stove): stoves hold out the possibility of greater efficiency, controllability and lower smoke emission than simple open fires. By enclosing the fire in a chamber and connecting it to a chimney draft (draught) is generated pulling fresh air through the burning fuel. This causes the temperature of combustion to rise to a point (~600°C) where efficient combustion is achieved, the enclosure allows the ingress of air to be regulated and losses by convection are almost eliminated. It also becomes possible, with ingenious design, to direct the flow of burned gasses inside the stove such that smoke particles are heated and destroyed. Enclosing a fire also prevents air from being sucked from the room into the chimney. This can represent a significant loss of heat as an open fireplace. Masonry heaters were developed to control air flow in stoves. A masonry heater is designed to allow complete combustion by burning fuels at full-temperature with no restriction of air inflow. Due to its large thermal mass the captured heat is radiated over long periods of time without the need of constant firing, and the surface temperature is generally not dangerous to touch. Tile stoves are a part of the interior design. A kitchen stove, cooker, or cookstove is a kitchen appliance designed for the purpose of cooking food. Kitchen stoves rely on the application of direct heat for the cooking process and may also contain an oven underneath it which is used for baking.



Disadvantage of all soil fuel direct heaters is that they need individual flues and their operation, the bringing in of fuel and removal of ashes, is rather messy.



Coal

Coal is a readily combustible black or brownish-black sedimentary rock normally occurring in rock strata in layers or veins called coal beds. The harder forms, such as anthracite coal, can be regarded as metamorphic rock because of later exposure to elevated temperature and pressure. Coal is composed primarily of carbon along with variable quantities of other elements, chiefly sulfur, hydrogen, oxygen and nitrogen. Coal, a fossil fuel, is the largest source of energy.

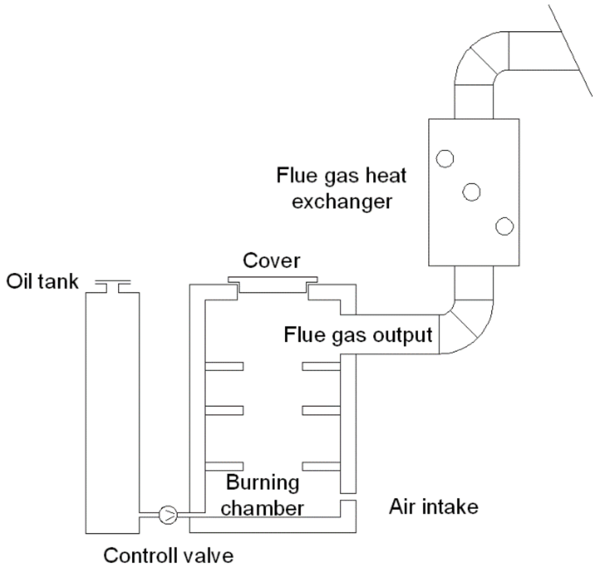
The classification of coal is generally based on the content of volatiles.
Heat content varies between 28-35MJ/kg.

Equipments: Solid Fuel Stoves.

Oil:

Heat content is 45MJ/kg

Oils stoves (Cast Iron Oil Heater):



Earth (Natural) Gas:

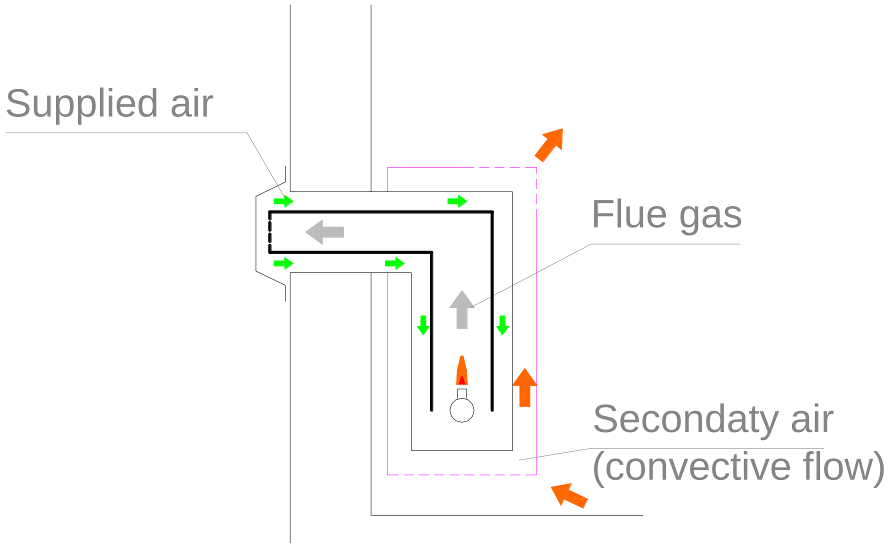
Physical Properties of Natural Gases

Components*:* Body of the Natural Gas (flammable components): Methan-CH4 ~96vol.%, Ethan-C_2H_6 ~1vol.%, Prophan-C_3H_8 ~1vol.%, Buthan-C_4H_{10} ~1vol.%, Penthan-C_5H_{12} ~1tf%
Escort substances: Carbon Dioxide, Nitrogen, Inert Gases)
Contaminants (Sulfur, Acid gases); Moisture

Stochiometric normal state: 15°C, 101325Pa. All the physical properties considered at that temperature and that pressure.
Relative density to air at any given temperature: Def: $s=\rho_{gas}/\rho_{air}$
Natural Gas: s=0.6 - 0.8
Calorimetric values:
Combustion heat (High): ~37 700 kJ/Nm3 – (moisture in water stage)
Heat content (Calorific value): ~34 000 kJ/Nm3 – (moisture in steam stage)
Ignition temperature: 500-700°C
Air demand: Natural gas: 9.5m3/m3 , Air access coefficient n =1.02 – 1.20

Equipments: Ceramic gas heater; Portable gas heater;

Wall mounted gas convector unit:



Electric heating:

Electricity has been labelled as the most convenient fuel. Because its ease of transport, ready controllability and the absence of combustion products. In countries where electric energy production is based on renewable sources (like hydro power plant) it is highly favoured for local heating. It is easier to run a cable to a room than pipe or ductwork.

Equipments: Infra red lamps;

The infra red lamp is incandescent lamp, designed fo have most of their output in the infrared range with very little light emission. They operate in a verz high temperature.

Oil filled panel emitters;

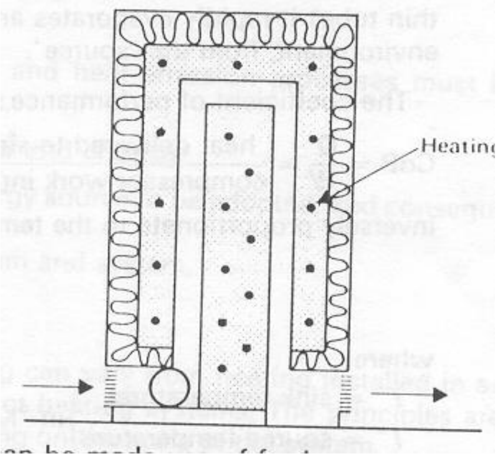
It’s a low temperature radiator panel. This type is usually mounted on castors. The electric resistance coil is enclosed in a thin tube which submerged in a volume of oil. The operation temperature of the panel is normally around 50°C

Fan convector;

In electric convectors the healing element is usually a bare resistance wire suspended between ceramic insulators, inside a casing, which is shaped to allow a natural convection current of air to develop through it. There are a number of units on the market transitional between this type and the incandescent radiator. The forced convector units use an element similar to this, but they incorporate a fan (either a propeller or a centrifugal type) to blow air across the element, which is thus kept at a tower temperature and is no longer incandescent. The heat emission is greatly improved.

Storage (block) heater;

The storage type or block heaters are based on the use of cheap off-peak electricity. The resistance elements heat up a mass of silica or ceramic material, which is enclosed in an insulated cabinet. A fan is include at the base, which can force room air through a duct formed in the storage mass. When the fan is not operating, the heat emission is quite small, but when switched on, it gives a reasonably fast response.

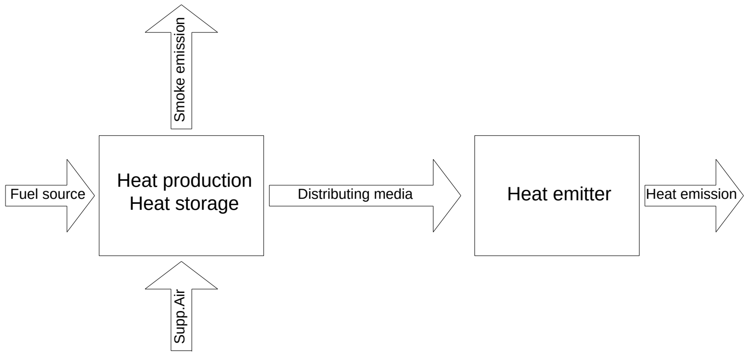


Ceiling and floor warming

A concrete floor can be made use of for heat storage purposes. Heating cables (not coils) can be la id in a serpentine pattern over a concrete floor and encased in a sand-cement screed of at least 50 mm thickness. The cables may be embedded or withdraw able (in conduits). The floor surface temperature would be 25-27°C, or up to 30°C if carpet is to be la id on top. Edge insulation should be provided, and in the case of a slab on ground also an approximately 1 m wide strip of under-floor insulation around the perimeter. The ground under the central parts will assist in the thermal storage. In the case of an intermediate floor there will be some downward heat emission. The ratio of upward to downward emission is inversely proportionate to the ratio of the resistance above the heating tables to the resistance between the tables and the ceiling below.

As floor warming is an essentially slow response system, it is often used only to provide background heating, while some other, quick response device is relied upon for 'topping up' when required. A variant of this is the ceiling warming system, where the heating tables are embedded in the plastering. As opposed to floor warming, this has a dominantly radiant emission, as the heated (lighter) air remains next to the ceiling surface.

Classification of heating systems according to the place of heat generation



- Local heating
- Central heating
- District heating

Generally

The term central heating covers hydronic heating systems with a central boiler or furnace either inside the building being heated or in the immediate vicinity.

Heat is generated in the boiler. Pipes carry the heated water to the building's heat sources (radiators) and return the cooled water to the boiler again.

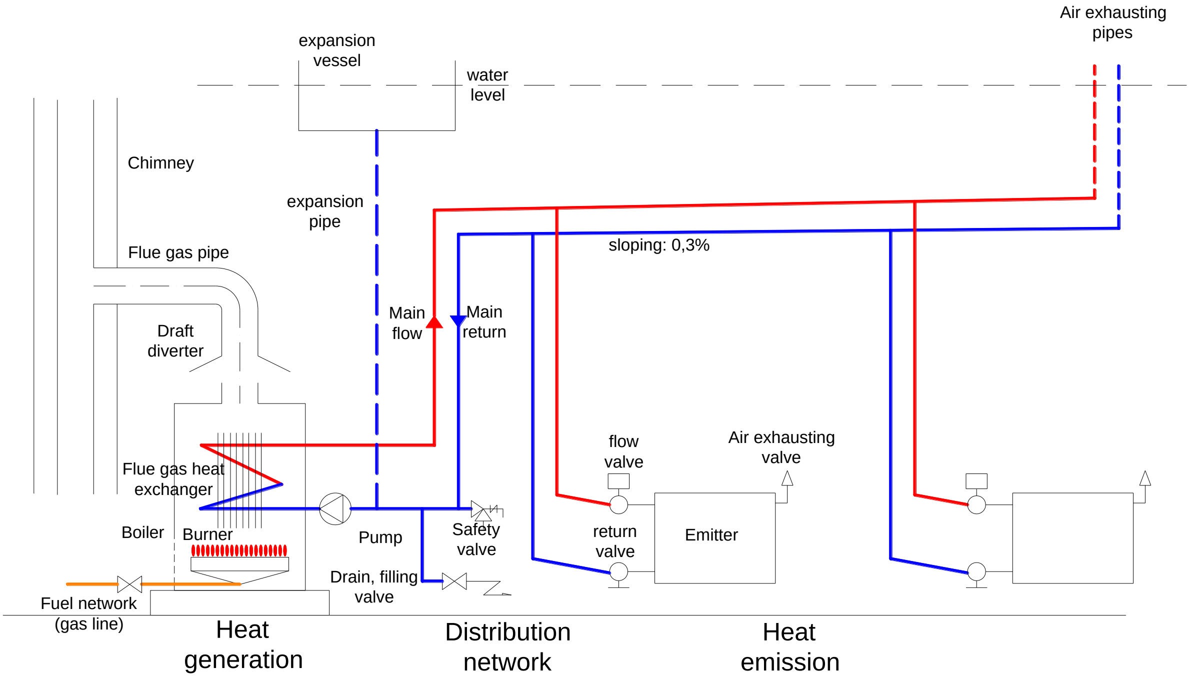
Originally, many central heating systems were designed to be self-circulating. Now a circulator is always used to pump heat through the system.

A wide range of fuel types are used in central heating. Coal, coke, wood, oil, gas, wood chips and wood pellets have all proven adequate fuel sources in central heating boilers.

Distributing media
Air (density ~1,2 kg/m3, specific heat ~1kJ/(kgK), temperature step ~6°C),
water (density ~1000 kg/m3, specific heat ~4,2kJ/(kg·K), temperature step ~10-20°C),
steam (specific heat of evaporation ~ 220kJ/kg)

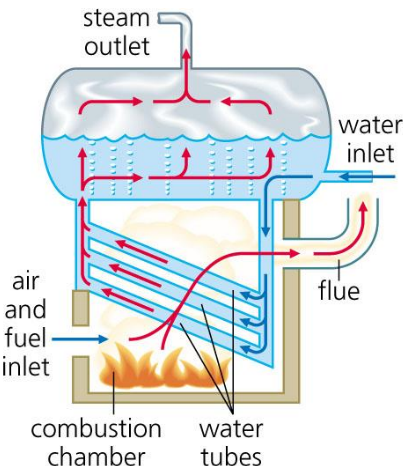
Heat emission:
Convection
Radiation

Main elements of water heating system:

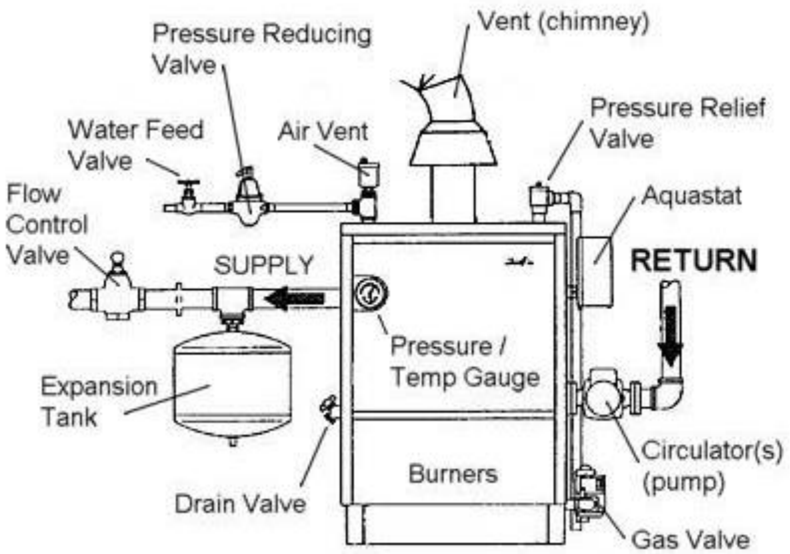


Boiler
Pump
Draft diverter
Flue gas pipe
Chimney
Flow and return pipe
Air exhausting valves
Drain and filling valve
Safety valve
Expansion vessel and pipe
Flow and return valves
Emitters

1. ***Boiler:***



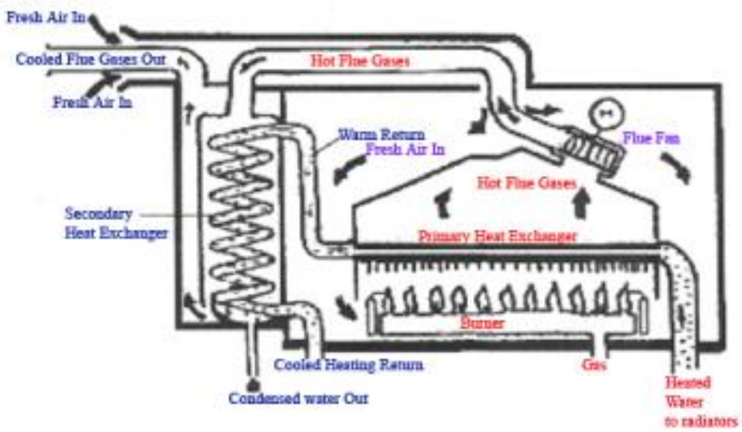
A boiler is a closed vessel in which water. The heated or vaporized fluid exits the boiler for use in heating applications. According to the fuel source there is gas, fire wood, coal, oil boilers. According to the way of air supply there are closed and opened burning chamber. According to the state of the vapour in the flue gas there are condensing and non condensing types***. Condensing boilers are the most energy efficient*** Central Heating boilers on the market today. They achieve this high level of efficiency by removing the heat from the fuel it is burning and also cooling the products of combustion, which are normally wasted up the flue, so much so that the water vapour in them turns into liquid. This happens at around 55°C. For a boiler to cool the flue products this much, it has to have a larger, more efficient heat exchanger than traditional boilers.



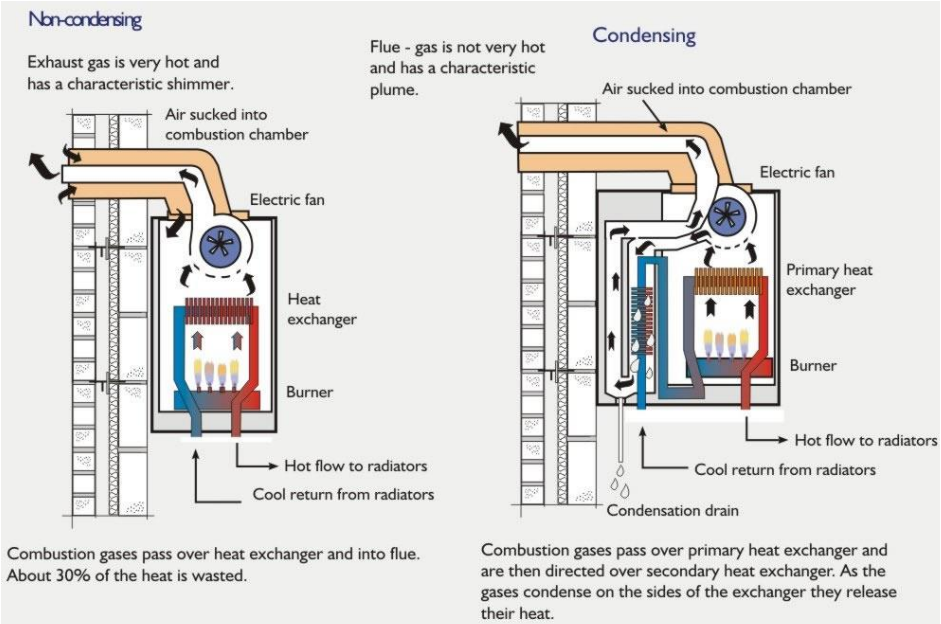
The efficiency is higher the flue leaving flue gas temperature is lower. So there are high temperature, medium temperature and low temperature types.

A condensing boiler utilizes the latent heat of water produced from the burning of fuel, in addition to the standard sensible heat, to increase its efficiency. In a conventional boiler, fuel is burned and the hot gases produced are passed through a heat exchanger where much of their heat is transferred to water, thus raising the water's temperature.

One of the hot gases produced in the combustion process is water vapour (steam), which arises from burning the hydrogen content of the fuel. A condensing boiler extracts additional heat from the waste gases by condensing this water vapour to liquid water, thus recovering its latent heat. A typical increase of efficiency can be as much as 10-12%. The effectiveness of this condensing process varies, it depends upon the temperature of the water returning to the boiler, but for the same conditions, it is always at least as efficient as a non-condensing boiler.



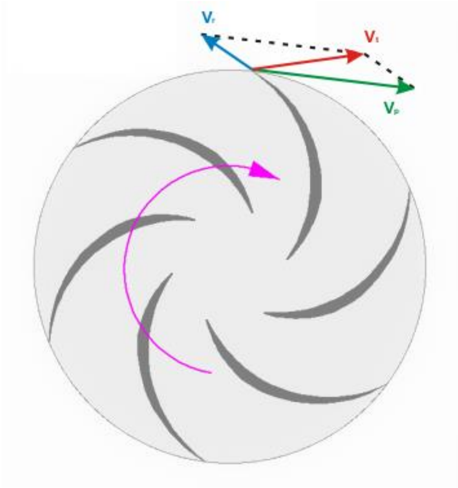
Condensing boiler manufacturers claim that up to 98% thermal efficiency can be achieved,[1] compared to 70%-80% with conventional designs (based on the higher heating value of fuels). Typical models offer efficiencies around 90%. The lower the return temperature to the boiler the more likely it will be in condensing mode. If the return temperature is kept below approximately 55°C the boiler should still be in condensing mode making low temperature applications such as radiant floors and even old cast iron radiators a good match for the technology.



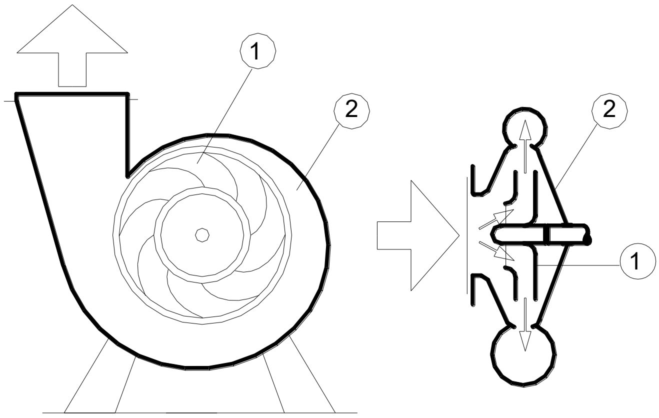
Pump

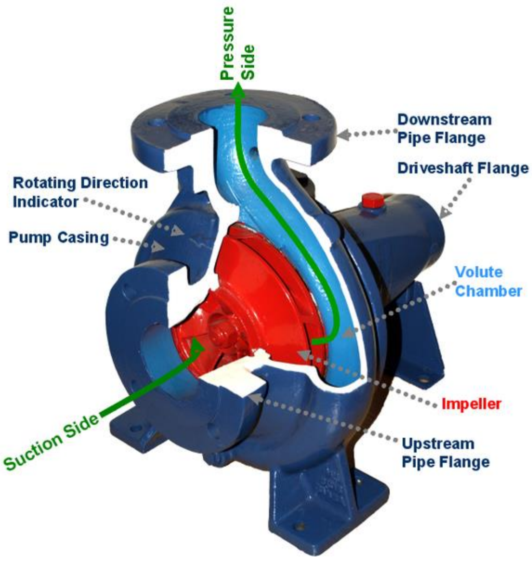
Aim: Procurement of positive pressure for maintaining the circulation of the water through the hydraulic circuit.

In general building service equipment centrifugal pump is most often used. A centrifugal pump is a rotodynamic pump that uses a rotating impeller to increase the velocity of a fluid. Centrifugal pumps are commonly used to move liquids through a piping system. The fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radially outward into a diffuser or volute chamber, from where it exits into the downstream piping system.

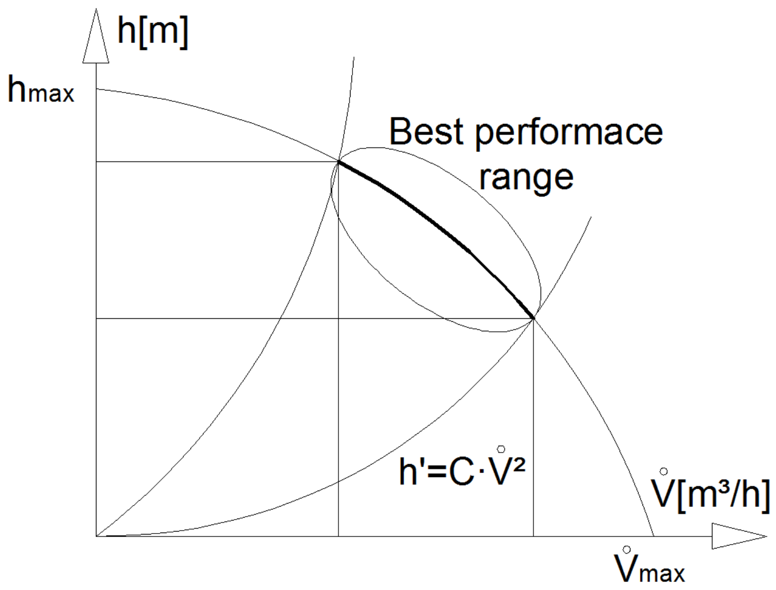


A centrifugal pump works on the principle of conversion of the kinetic energy of a flowing fluid (velocity pressure) into static pressure. This action is described by Bernoulli's principle. The rotation of the pump impeller accelerates the fluid as it passes from the impeller eye (centre) and outward through the impeller vanes to the periphery. As the fluid exits the impeller, a proportion of the fluid momentum is then converted to (static) pressure. Typically the volute shape of the pump casing, or the diffuser vanes assist in the energy conversion. The energy conversion results in an increased pressure on the downstream side of the pump, causing flow.





Characteristic(performance) curve of centrifugal pumps



The pump performance curve shows the correlation between media flow (V) and the pressure differential or head (h) that the pump creates.

For variable-speed pumps, the performance curve is given at minimum and maximum RPM.

When several pumps are connected, the final performance curve is achieved by combining the characteristics of the individual pumps.

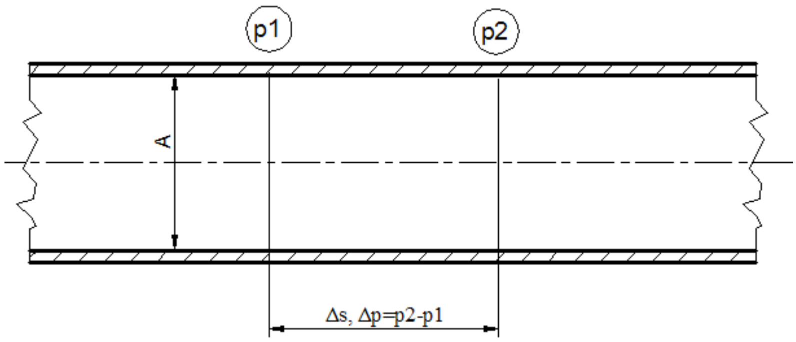
Parallel-connected pumps are added horizontally to increase V. For two identical pumps, the maximum V will double, yet maximum H will be the same. This principle is commonly used in pump systems.

Series-connected pumps are added vertically to increase h. For two identical pumps, the maximum h will double. Maximum V will remain the same. This principle is commonly used in multi-stage pumps.

The performance curve is used together with the system characteristics when dimensioning and selecting pumps.

Energy usage:

The energy usage in a pumping installation is determined by the flow required, the height lifted and the length and friction characteristics of the pipeline.



The power required to drive a pump (P), is defined simply using SI units by using the definition of work:

$$P_{theoretical}[W] = \frac{F \cdot \Delta s}{t}$$

$$P_{theoretical}[W] = \frac{\Delta p \cdot A \cdot \Delta s}{t} = \frac{\Delta p \cdot V}{t} = \Delta p \cdot \dot{V}$$

$$P_{theoretical}[W] = \dot{V}\,\Delta p$$

$$P_i[W] = \frac{\dot{V}[m^3/s] \cdot \Delta p[Pa]}{\eta} = \frac{\dot{V}\, H \cdot \rho \cdot g}{\eta}$$

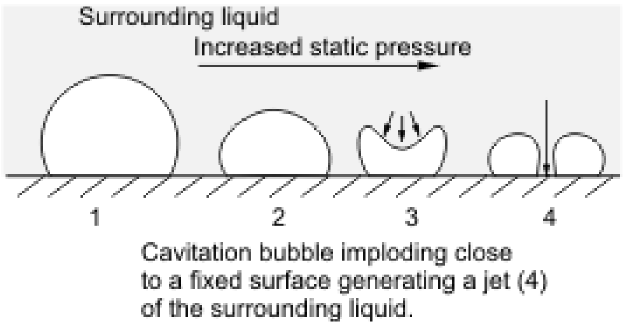
where:

P_i is the input power required (W)
ρ is the fluid density (kg/m^3)
g is the standard acceleration of gravity (9.80665 m/s^2)
H is the energy Head added to the flow (m)
$\dot{V}$ is the flow rate (m^3/s)
η is the efficiency of the pump plant as a decimal

The head added by the pump (H) is a sum of the static lift, the head loss due to friction and any losses due to valves or pipe bends all expressed in meters of fluid. Power is more commonly expressed as kilowatts (10^3 W). The value for the pump efficiency η may be stated for the pump itself or as a combined efficiency of the pump and motor system.

The **energy usage** is determined by multiplying the power requirement by the length of time the pump is operating.

Problems of centrifugal pumps:



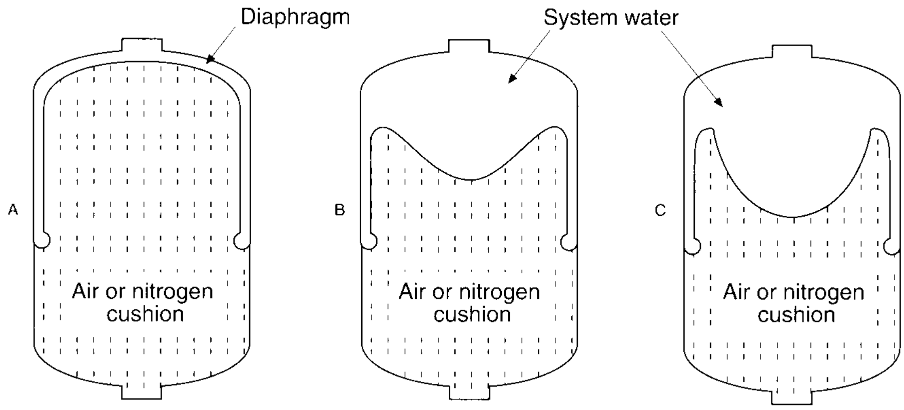
Cavitation:
Cavitation is the formation of gas bubbles of a flowing liquid in a region where the pressure of the liquid falls below its vapor pressure. Cavitation occurs when a liquid is subjected to rapid changes of pressure causing the formation of gas or vapor bubbles in the lower pressure regions of the liquid. When entering high pressure areas these bubbles collapse on a metal surface continuously, they cause cyclic stressing of the metal surface. This results in surface fatigue of the metal causing a type of wear called cavitation. The most common examples of this kind of wear are pump impellers and bends when a sudden change in the direction of liquid occurs.

Wear of the Impeller—can be worsened by suspended solids
Corrosion inside the pump caused by the fluid properties
Overheating due to low flow
Leakage along rotating shaft
Lack of prime—centrifugal pumps must be filled (with the fluid to be pumped) in order to operate

Expansion vessel

Closed and opened systems:

An expansion tank or expansion vessel is a small tank used in ***closed water heating systems*** to absorb excess water pressure, which can be caused by thermal expansion as water is heated, or by water hammer. The vessel itself is a small container divided in two by a rubber diaphragm. One side is connected to the pipe work of the heating system and therefore contains water. The other, the dry side, contains air under pressure, and normally a *Schrader* valve (car-tire type valve stem) for checking pressures and adding air. When the heating system is empty or at the low end of the normal range of working pressure the diaphragm will be pushed against the water inlet. As the water pressure increases, so the diaphragm moves compressing the air on its other side. The compressibility of the air cushions the pressure shock, and relieves pressure in the system that could otherwise damage the plumbing system.



A. When system is filled, no water enters tank when cushion and water pressure are in equilibrium

B. As temperature increases, diaphragm moves to accept expanded water

C. When water rises to maximum, full acceptance of expansion is achieved

Prior to the use of sealed expansion tanks, 'open' tanks were installed in the roof space to accommodate the water's expansion; these had the disadvantage of being exposed to the cold air in the roof space. This, without effective loft insulation, could fall below freezing, and could cause the pipework supplying the tank to freeze. However with good pipe and tank insulation, this was in practice quite rare. Although such systems were remarkably trouble free, there are concerns about the potability of water from roof tanks due to the possibility of contamination. The other major disadvantage is that the water pressure from a roof tank is considerably lower than mains water pressure, making the use of mixer taps sometimes unpredictable.

Necessary size of the expansion vessel depends on the total volume of the heating system. Under standard circumstances the net volume of the expansion vessel is approximately 10% of the total volume of a heating system.

Air Venting

To prevent corrosion and problems with operation, heating and air-conditioning system must be constructed so that air can be removed when the system is filled as well as during subsequent operation.

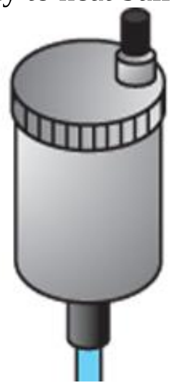
Air can still be present in a system filled with water even after the system has been vented using air vent screw and air vents. This is because the water contains certain volume of air, depending on ambient pressure and temperature at the time the system is filled.

The air is released when the water is heated in the boiler or heat exchanger and in low pressure areas in the system, such as at the highest point in the system on or the suction side of a pump. The released air consists of oxygen and nitrogen. The oxygen binds to any iron material in the system. Micro-bubbles of the remaining nitrogen gases must be removed by another means.

The following are commonly used components and methods to remove air:

- Air vent screw mounted on radiators and convectors
- Automatic air vents which are placed at highs points on the system, often where the pipe goes from horizontal to a vertical drop
- Micro-bubble air vents located in front of main pumps where the pressure is lowest

Air that is not removed from the system will collect at high point in the heating system and create air pockets. Worst case in the circulation in the heating system comes to a standstill, and the system loses its ability to heat building.



Hydraulic System of a water heating network

Aims: Volume flow rates, diameters, pressure losses, selecting pump, adjusting the parallel sections.

Volume flow rates:

Heat transport trough the pipe can be calculated by the simplified form of the second law of thermo dynamics:

$$\dot{Q} = \dot{m} \cdot c \cdot \Delta t = \dot{V} \cdot \rho \cdot c \cdot \Delta t$$

$$\dot{V} = \frac{\dot{Q}}{\rho \cdot c \cdot \Delta t}$$, thus

Volume flow rate of parallel sections is

$$\dot{V} = \sum \dot{V}_j$$

Determining the pipe diameter of a water heating system:

Simplified method:

The simplified method is based on the maximum velocity of a pipe network. Reason of maximizing the velocity is related to the pressure loss function:

$$\Delta p' = p_d \cdot \left(f \cdot \frac{\sum L}{D} + \sum \xi \right) = \frac{\rho}{2} \cdot v^2 \cdot \left(f \cdot \frac{\sum L}{D} + \sum \xi \right) = Const \cdot v^2$$

In the equation it is clear that the pressure loss due to friction is square function of a velocity. The other reason is the acoustic noise development, which also positively depends on the velocity of a moving fluid. The velocity range in the pipe network for heating systems is v_{max}=1m/s. For sizing the inner diameter the best initial value is 0,5m/s.

Based on the continuity the equation for the inner diameter can be developed:

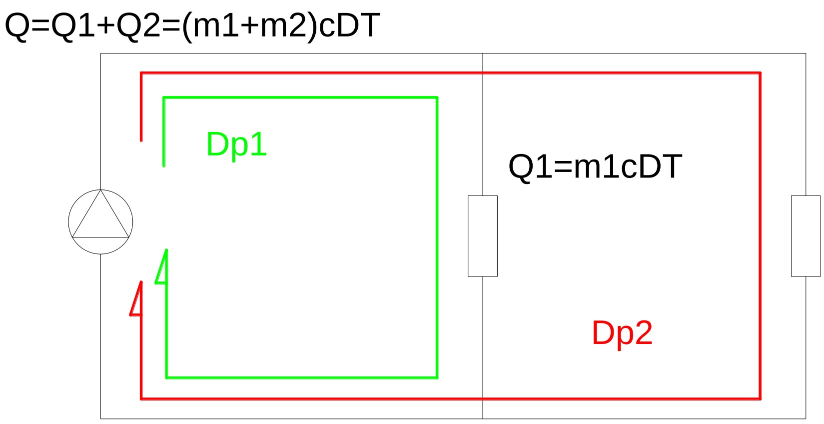
$$\dot{V}[m^3/s] = v \cdot A = v \cdot \frac{d^2 \pi}{4}$$

$$d^2 = \frac{4 \cdot \dot{V}}{v \cdot \pi}$$

$$d = \sqrt{\frac{4 \cdot \dot{V}}{0.5 \cdot \pi}} = \sqrt{\frac{8 \cdot \dot{V}}{\pi}}$$

$$d_{min} = \sqrt{\frac{4}{v \cdot \pi} \frac{\dot{Q}}{\rho \cdot c \cdot \Delta t}} = \sqrt{\frac{8}{\pi} \frac{\dot{Q}}{\rho \cdot c \cdot \Delta t}}$$

Pressure loss method (finding the hydraulically most remote circuit):

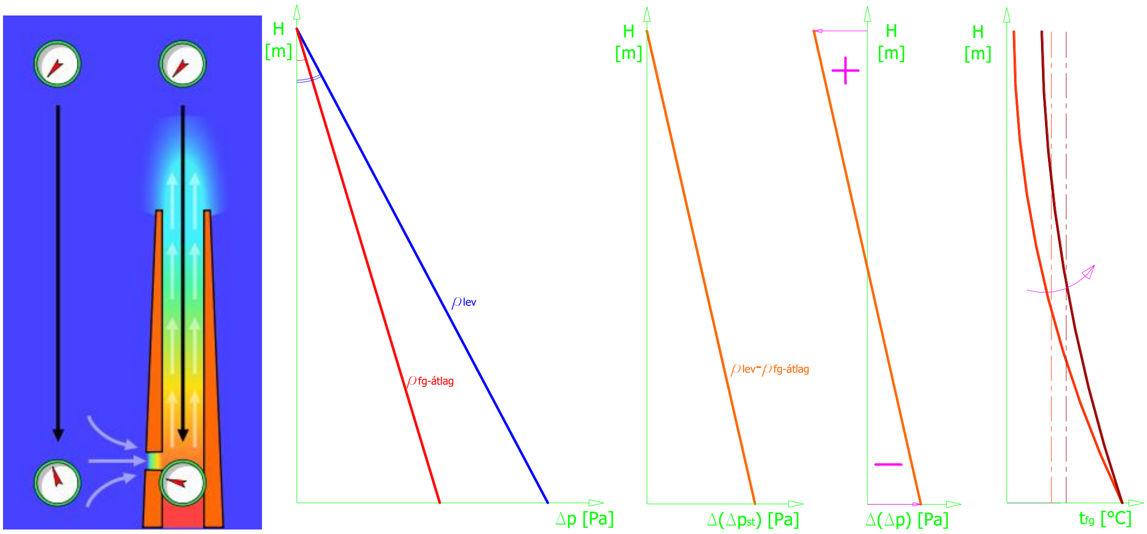


Chimney:

A chimney is a structure for venting hot flue gases or smoke from a boiler, stove, furnace or fireplace to the outside atmosphere. Chimneys are typically vertical, or as near as possible to vertical, to ensure that the gases flow smoothly, drawing air into the combustion in what is known as the stack, or chimney, effect. The space inside a chimney is called a flue.

The combustion flue gases inside the chimneys or stacks are much hotter than the ambient outside air and therefore less dense than the ambient air. That causes the bottom of the vertical column of hot flue gas to have a lower pressure than the pressure at the bottom of a corresponding column of outside air. That higher pressure outside the chimney is the driving force that moves the required combustion air into the combustion zone and also moves the flue gas up and out of the chimney. That movement or flow of combustion air and flue gas is called "natural draught/draft", "natural ventilation", "chimney effect", or "stack effect". The taller the stack, the more draught or draft is created. There can be cases of diminishing returns where a stack that is overly tall in relation with the heat being sent out of the stack where the flue gases cool prior to reaching the top of the chimney. This condition can result in poor drafting and in the case of wood burning appliances the cooling of the gases prior to exiting the chimney can cause creosote to form near the top of the chimney.

Designing chimneys and stacks to provide the correct amount of natural draught or draft involves a number design factors, many of which require trial-and-error reiterative methods.

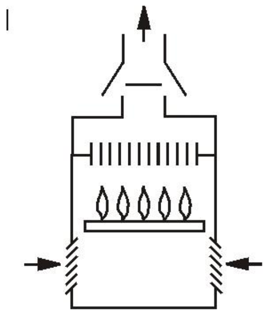


Draft:

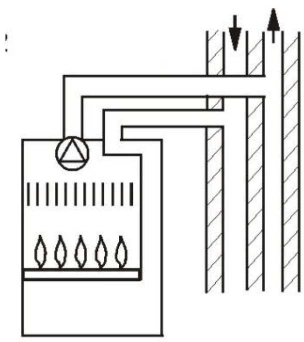
$$\Delta p_{draft} = \left(\frac{T_0}{T_0 + t_{air}} - \frac{T_0}{T_0 + t_{average-fluegas}}\right)\rho_0 g H$$

Chimney and the equipment (main chimney types):

Equipment with open combustion chamber (equipped with draft diverter):



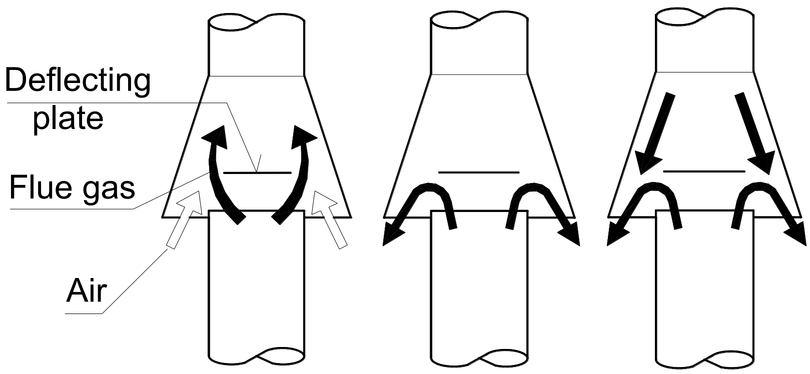
Equipment with closed combustion chamber (two individual pipes)



Pressure loss of flue gas path:

$$\Delta p_{draft} = \Delta p' = \Delta p'_{Air\,supp.} + \Delta p'_{Equipment} + \Delta p'_{Fluegaspipe} + \Delta p'_{Chimney} + \Delta p'_{ChimneyOutlet}$$

Draft diverter:

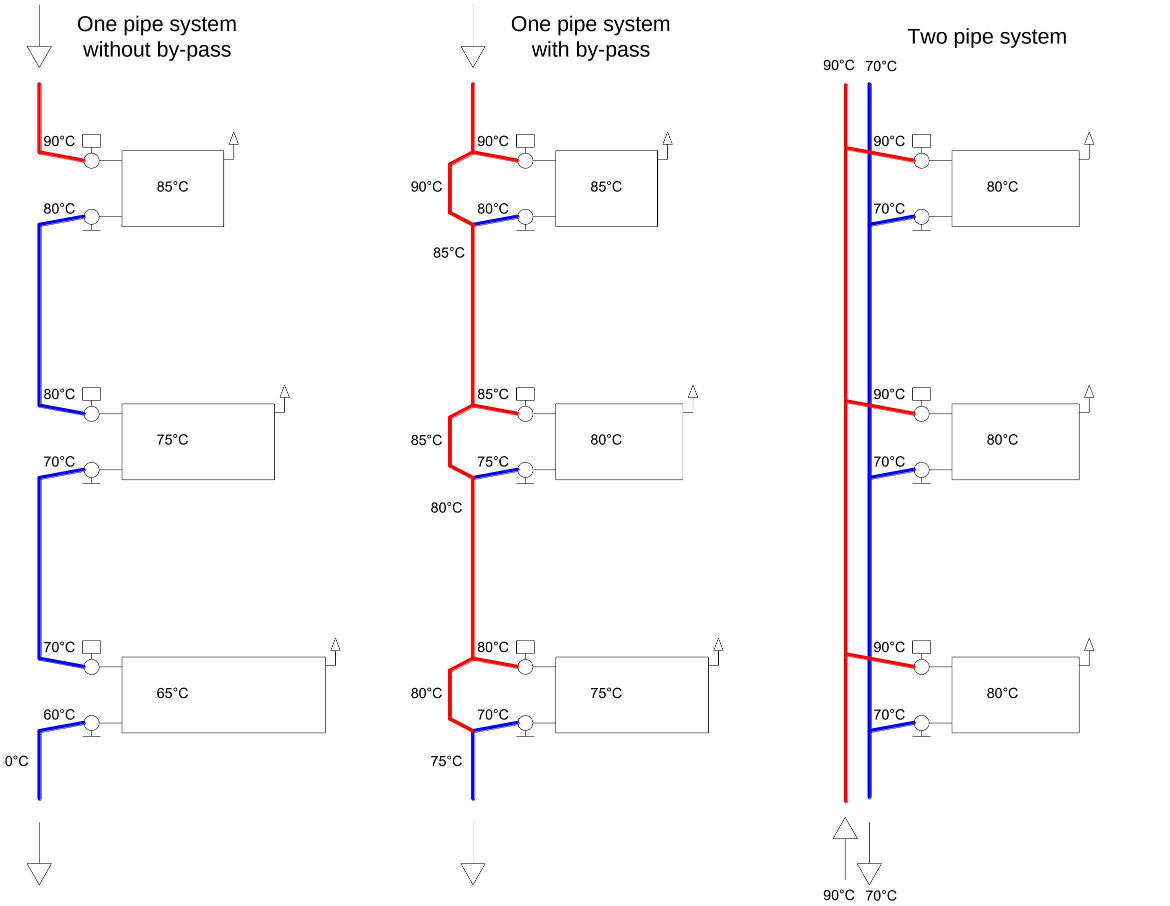


1. Normal operation
2. Start of the boiler, no draft effect because of cold chimney body
3. Draft stop (wind)

Distributing network:

There are two basic categories of pipe systems: one-pipe and two-pipe systems. The type of system installed will have an influence on dimensioning radiators and piping. A general characteristic of a two-pipe system is that the radiators are dimensioned for the same flow temperature and the same temperature difference.

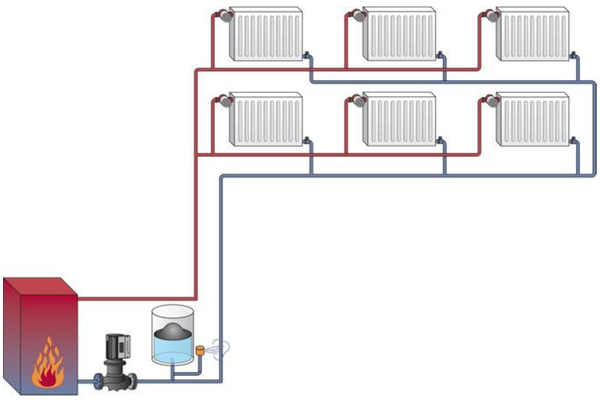
Comparison of one pipe (with and without by-pass) and two pipe systems:



Distribution network for large multi-storey buildings:

Two pipe systems:

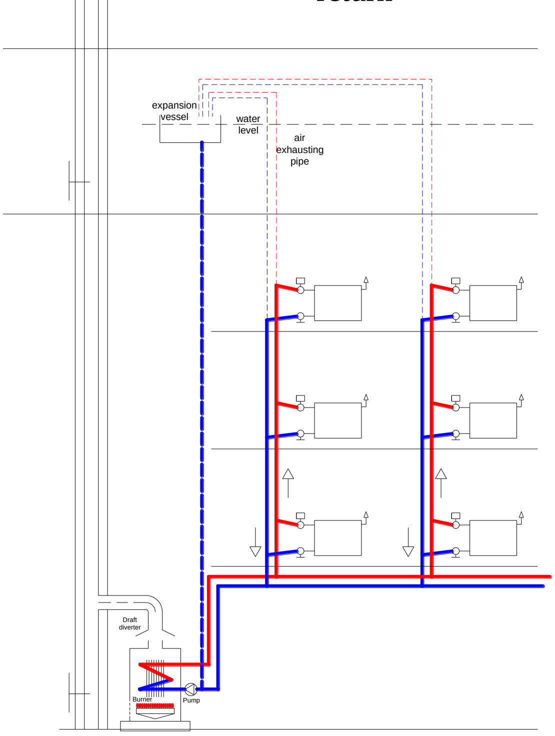
Two-pipe system with direct return
In a two-pipe direct return system, the total pipe length from the pump to and from each radiator is shorter for the radiators closer to the pump and longer for the more distant radiators. For this reason, the differential pressure can be significantly higher at the closest radiator than at the most distant radiator. This must be taken into consideration when designing the system. The advantage of the direct return system is that pipe routing is more straightforward compared to the reverse return system.



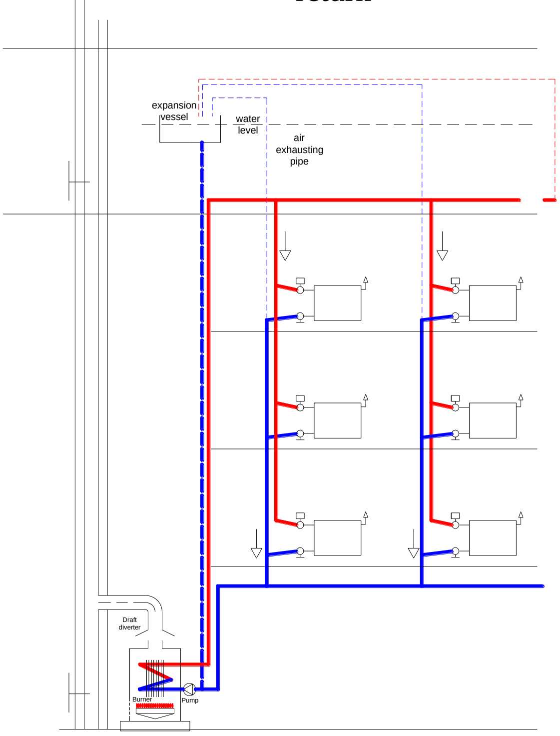
Two-pipe system with reverse return (Tichelmann system)
In a two-pipe reverse return system, the total pipe length from the pump to and from each radiator is the same for all radiators on the same story. This gives a favorable water distribution.

Two–pipe system with overhead piping
The distribution pipe is located in the suspended ceiling, and air vents are installed in central positions. This type of system is common in larger buildings as it is relatively easy to balance and regulate the system. It is also easy to extend the system.

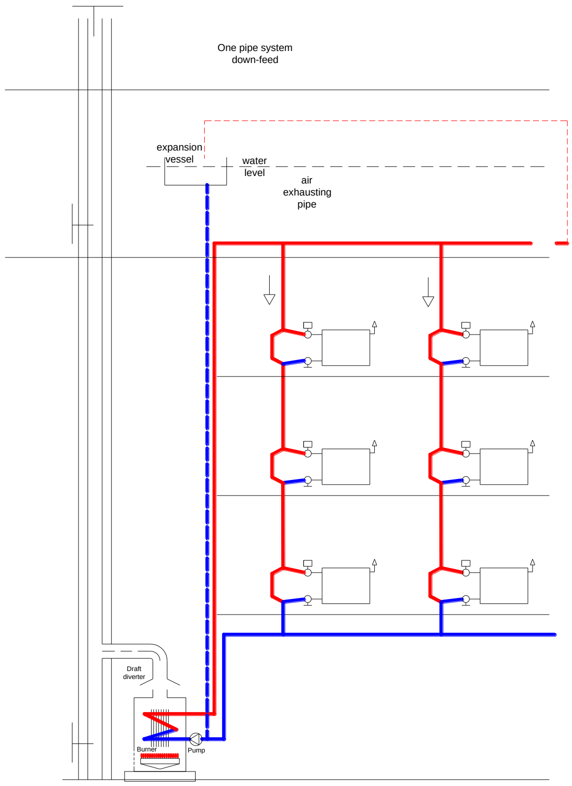
Two pipe system with direct return

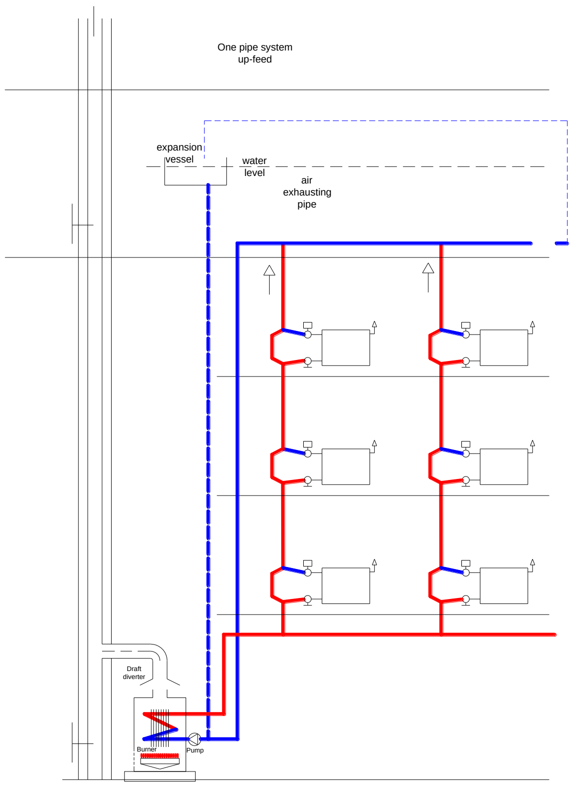


Two pipe system with reverse return



One pipe systems with by-pass:





Pipe materials:
Zincked, screwable steel pipe with longitudinal welt
Copper,
Polyethylene
Hydraulically balanced networks

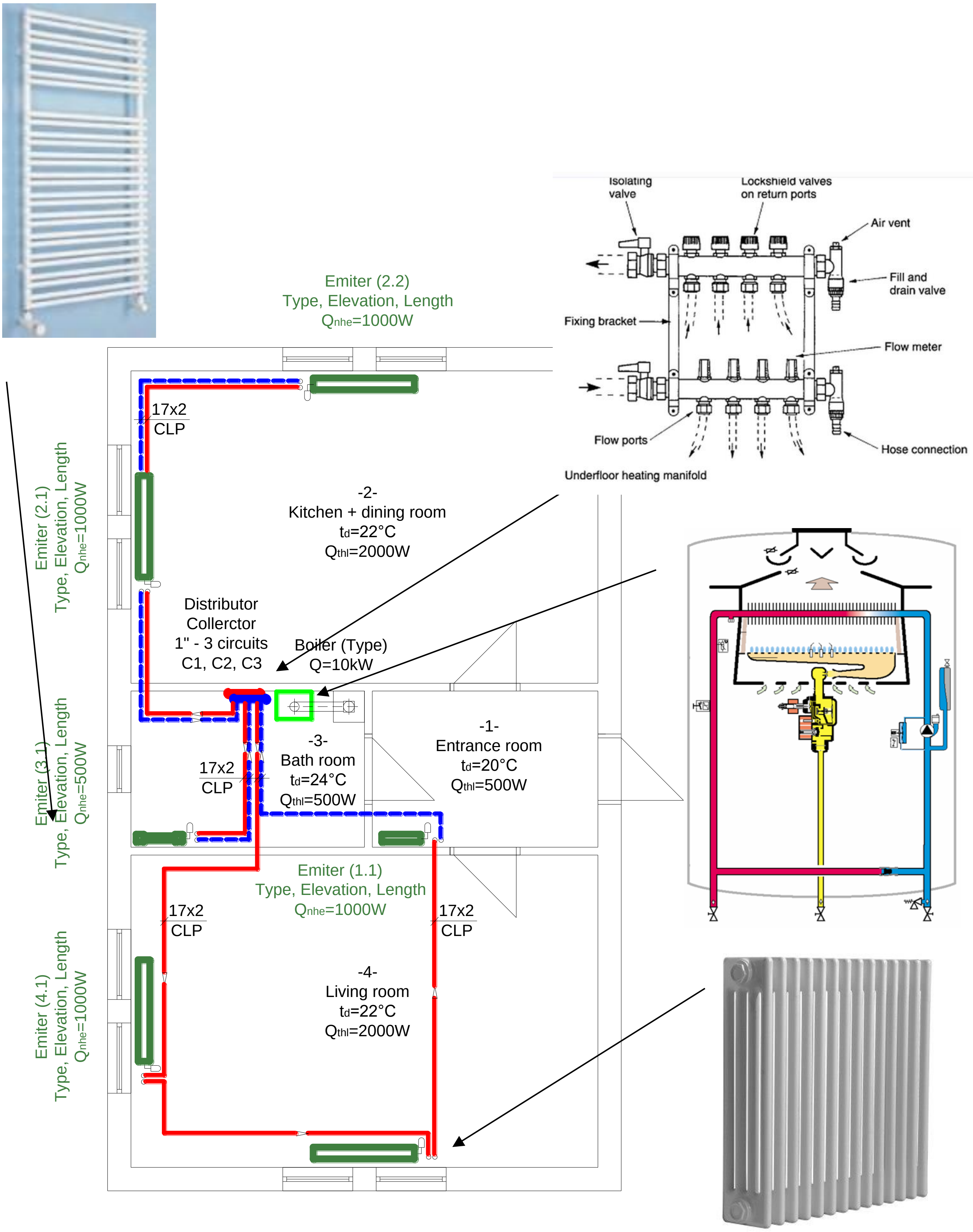
Two-pipe system with underfloor piping:

This system is common in houses and in buildings where the piping cannot be fitted in the available ceiling space. The distribution pipes are placed under the floor.

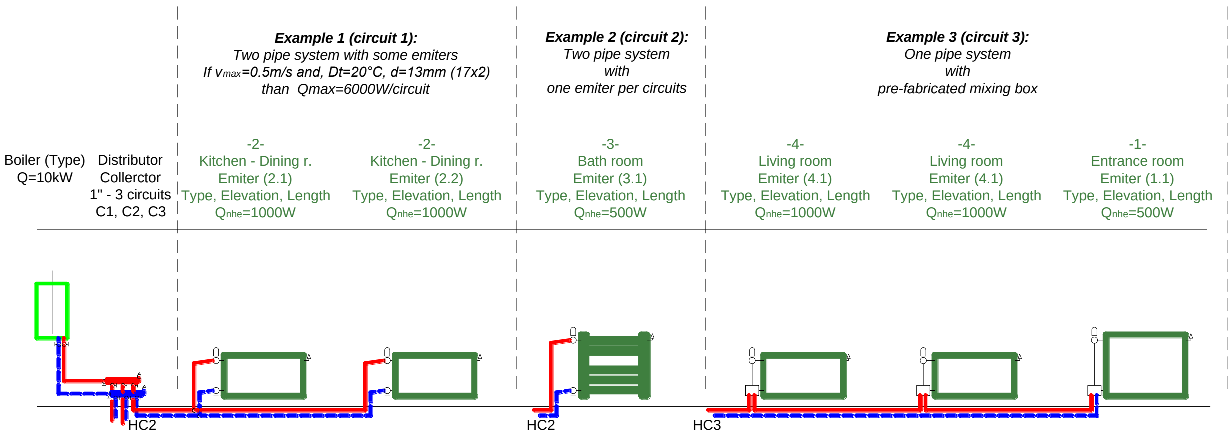
Total heat loss - fabric losses (surface losses, linear losses), filtration loss
Boiler: Place, chimney (main geometrical parameters), deign parameters (Produced nominal heat, size of the flue gas pipe)
Emiters: place, types, size, nominal heat emission
Main distribution ideas:

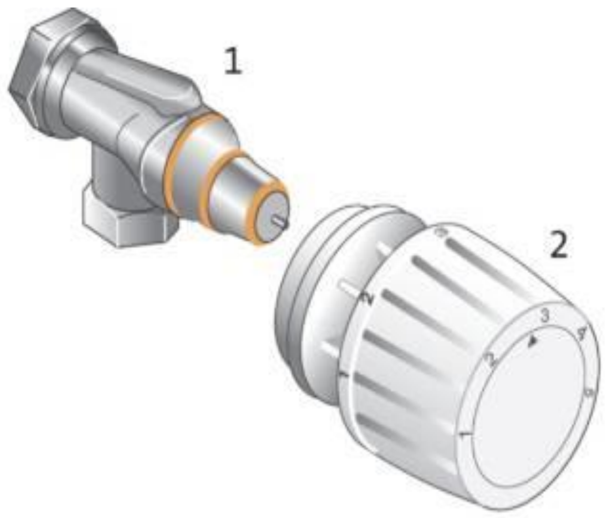
Main distribution network between distributor and collector (~pipe size: 25mm)
Distributor – collector : place, size, number of circuits
Pipe – case one: laying in the concrete, size (10-16mm, 2 – 9kW/circuits), plastic
Pipe – case two: distribution network is under the ceiling, size, material
Two pipe systems – some emitter per circuits
One pipe systems – some emitter per circuits
One emitter per circuits

Heating systems for One-floor heating:



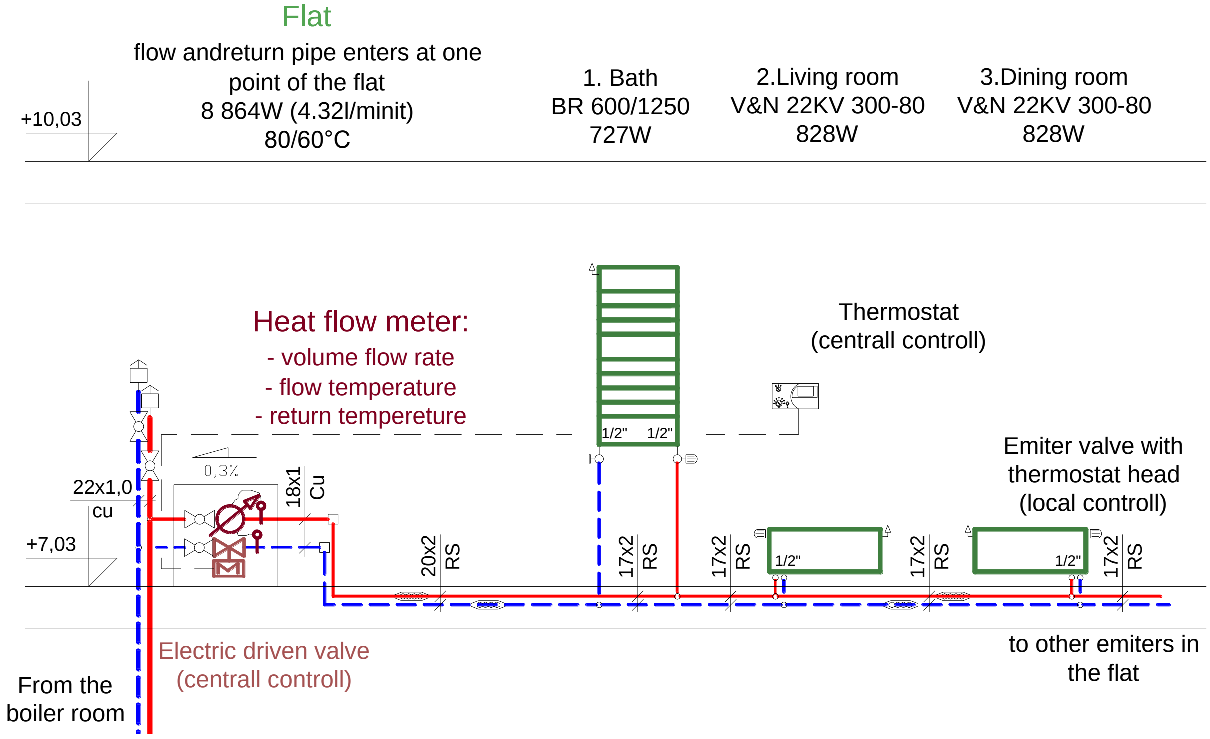
Elevation circuit diagram:





A thermostatic radiator valve is fitted on radiators and convectors to regulate room temperature. The valve functions automatically and is comprised of two parts: a sensor and a valve casing. The valve casing is fitted directly on the radiator or on the radiator supply pipe. The sensor is fitted to the valve casing.
The sensor can have a built-in or remote sensor. Remote sensors can be used if the radiator is located behind a screen/cover, which would otherwise cause inaccurate room temperature readings if mounted directly on or by the radiator.

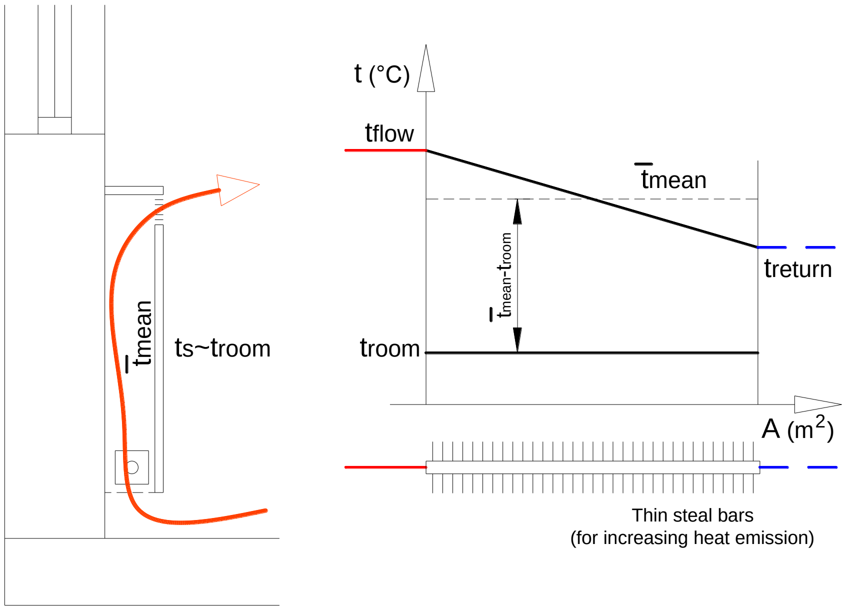
Demandcontrol:



Emitter:

Regardless of how the hit is transported to the room, the type and arrangement of emitters have the most direct influence on thermal comfort. According to how the heat is emitted we extinguish convectors and radiators.

Convector:
There is no ideal convector. Part of the heat from the convector is transported by radiation also. The simplest arrangement of convectors is the ***wall mounted convector unit***:



The air circulation in between the room and the convector unit relays on natural convection. The driving force is the temperature difference ($\bar{t}_{mean} > t_{room}$).
The heat transfer process relays on the convection. The governing equation of the convection process:

$$\dot{Q} = A \cdot U \cdot (\bar{t}_{mean} - t_{room})$$

The simplified method of calculating the mean temperature of the emitter is the mathematical average:

$$\bar{t}_{mean} = \frac{t_{flow} + t_{return}}{2}$$

Thus:

$$\dot{Q} = A \cdot U \cdot \left(\frac{t_{flow} + t_{return}}{2} - t_{room} \right)$$

From the equation above it is clear that the heat emission depends on the flow and return temperature, the room temperature and the surface of the emitter. In one particular emitter the heat emission only depends on the temperatures.

Based on standard temperatures, mean temperature different can be identified:

$$\Delta\bar{t}_0 = \left(\frac{t_{flow,0} + t_{return,0}}{2} - t_{room,0}\right) = \frac{90 + 70}{2} - 20 = 60\,°C$$

Heat emission of the emitter is compared to the standard case by the following equation:

$$\dot{Q} = \dot{Q}_0 \cdot \left(\frac{\Delta\bar{t}}{\Delta\bar{t}_0}\right)^n$$

Where $\Delta\bar{t}$ is the real mean temperature different, n represents the type specification of a particular emitter (n=1-1.5).
Substituting $\Delta\bar{t}_0$, and $\Delta\bar{t}$:

$$\dot{Q} = \frac{\dot{Q}_0}{60^n} \cdot \left(\frac{t_{flow} + t_{return}}{2} - t_{room}\right)^n$$

Example 1:

Under standard circumstances the wall mounted convector units emits 1000W heat. The emitter constant is n=1.3. The flow and the return temperature of the heating system are 70/55°C, the temperature or the room is 22°C.

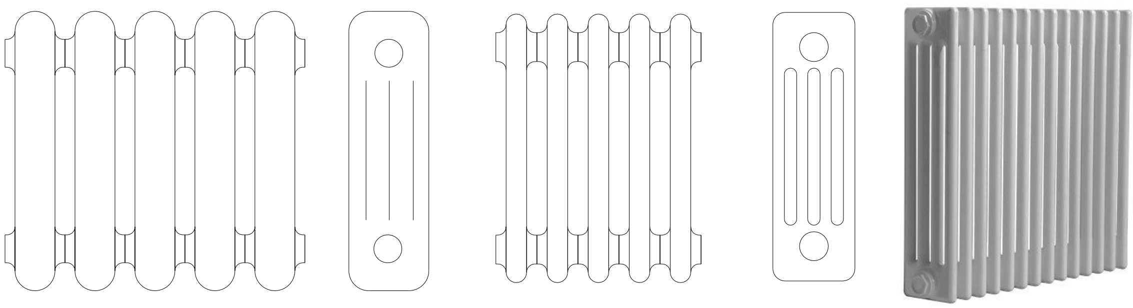
$$\dot{Q} = \frac{\dot{Q}_0}{60^n} \cdot \left(\frac{t_{flow} + t_{return}}{2} - t_{room}\right)^n = \frac{1000}{60^{1,3}} \cdot \left(\frac{70 + 55}{2} - 22\right)^{1,3} = 1000 \cdot \left(\frac{40.5}{60}\right)^{1,3} = 1000 \cdot 0.6 = 600\text{W}$$

Radiator:
Ideally only radiant heat occurs when there is no any air movement around the emitter. Typical examples are surface heating (floor and ceiling). But because vertical surfaces are irradiated, those surfaces become hotter than the ambient room temperature convective heat transport is also developing.

In general case emitter emits heat by convection and radiation.

Different type of emitters:

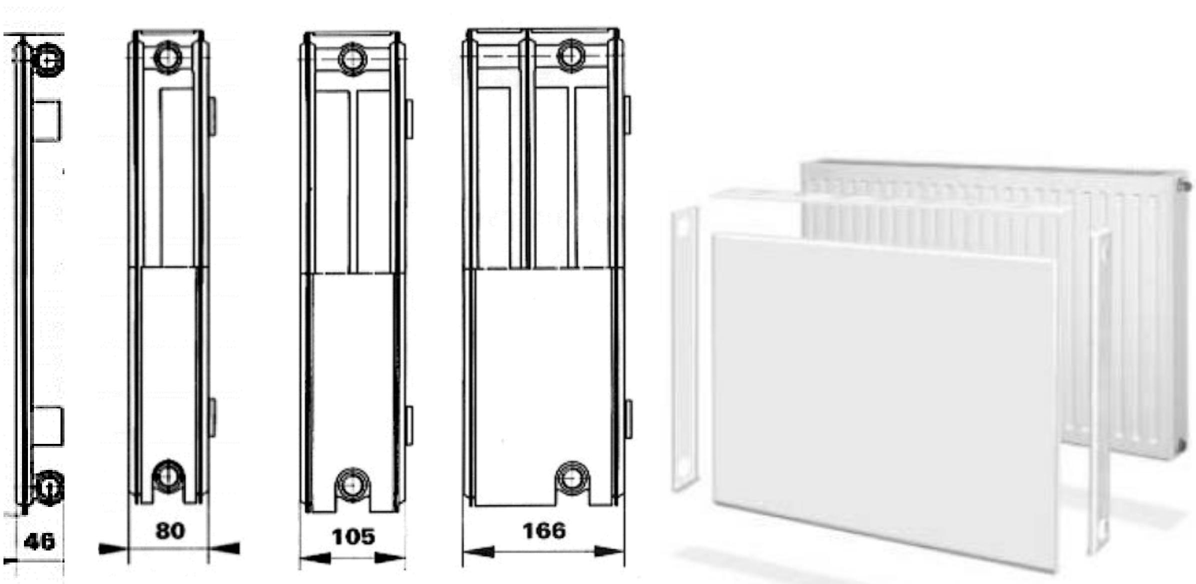
Column radiators:
The name indicates that most of the heat emitted by those equipments by radiation:



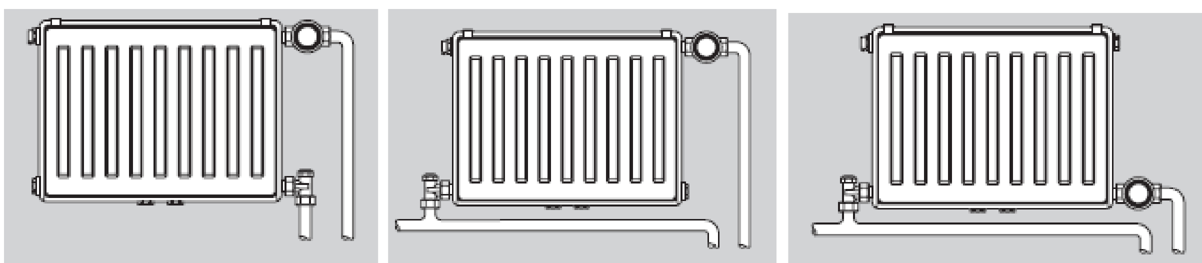
Hospital type, two, tree, four, five column type (Cast Iron); Pressurized steel.

Selecting the column type emitters:
Under standard circumstances for a particular emitter (which is always the elevation and the types) heat emission of one unit is given. Sizing of the emitter means estimating of a number of column units.

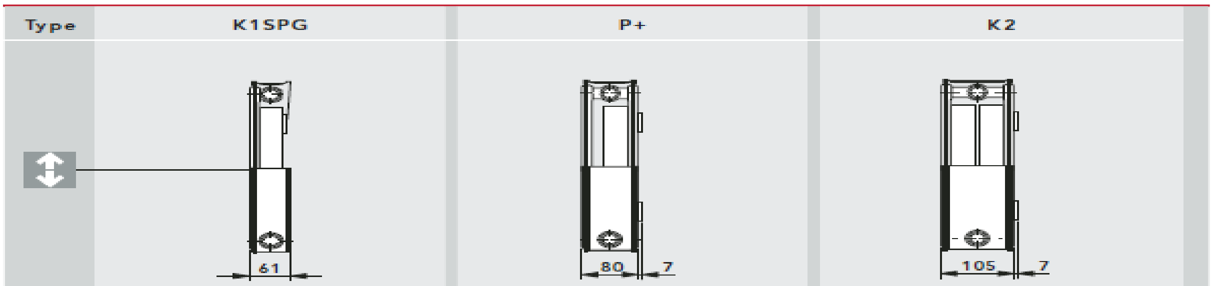
Panel emitters:



Possible connections:



Selecting panel emitters:



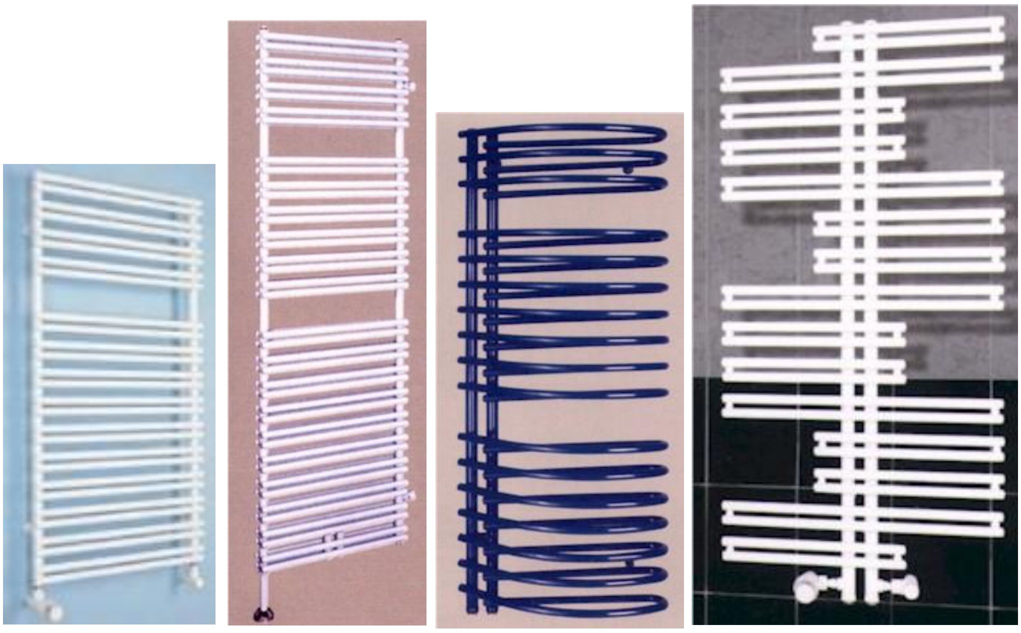
Heat outputs based on a mean radiator water temperature of 80 °C and room temperature of 20 °C Delta T 60.

Heigth (mm)			300			400			500			600			750			
Model / Length (nominal)			K1 SPG	P+	K2	K1 SPG	P+	K2	K1 SPG	P+	K2	K1 SPG	P+	K2	K1 SPG	P+	K2	out-put
mm	in	secs																
400	15,7	10	288	427	558	362		695	431	634	823	498	729	943	593	863	1108	Watt
			983	1457	1904	1234		2370	1471	2165	2807	1700	2487	3217	2022	2943	3780	BTU
520	20,4	13							560	825	1069	648	948	1226				Watt
									1912	2814	3649	2210	3233	4182				BTU
600	23,6	15	432	640	837	543		1042	647	952	1234	747	1093	1414	889	1294	1662	Watt
			1474	2185	2856	1851		3555	2207	3247	4210	2550	3731	4826	3033	4415	5670	BTU
720	28,3	18							776	1142	1481	897	1312	1697	1067	1553	1994	Watt
									2648	3897	5052	3060	4477	5791	3639	5298	6804	BTU
800	31,5	20	576	854	1116	723		1389	862	1269	1645	997	1458	1886	1185	1725	2216	Watt
			1965	2914	3808	2468		4740	2942	4330	5613	3400	4974	6434	4044	5887	7560	BTU
920	36,2	23							992	1459	1892	1146	1676	2169	1363	1984	2548	Watt
									3383	4979	6455	3910	5720	7399	4650	6770	8694	BTU
1000	39,4	25	720	1067	1395	904		1737	1078	1586	2056	1246	1822	2357	1481	2156	2769	Watt
			2457	3642	4761	3085		5925	3678	5412	7017	4250	6218	8043	5055	7358	9450	BTU
1120	44,1	28							1207	1776	2303	1395	2041	2640	1659	2415	3102	Watt
									4119	6062	7859	4761	6964	9008	5661	8241	10584	BTU
1200	47,2	30	864	1281	1674	1085		2084	1293	1903	2468	1495	2187	2829	1778	2588	3323	Watt
			2948	4370	5713	3703		7110	4413	6495	8420	5101	7461	9651	6066	8830	11340	BTU
1320	52,0	33							1423	2094	2714	1644	2405	3111	1955	2847	3656	Watt
									4854	7144	9262	5611	8208	10617	6672	9713	12474	BTU
1400	55,1	35	1008	1494	1953	1266		2431	1509	2221	2879	1744	2551	3300	2074	3019	3877	Watt
			3440	5099	6665	4320		8296	5149	7577	9824	5951	8705	11260	7077	10302	13230	BTU
1600	63,0	40	1152	1708	2232	1447		2778	1724	2538	3290	1993	2916	3771	2370	3450	4431	Watt
			3931	5827	7617	4937		9481	5884	8659	11227	6801	9949	12869	8088	11773	15120	BTU
1800	70,9	45	1296	1921	2511	1628		3126	1940	2855	3702	2242	3280	4243	2667	3882	4985	Watt
			4422	6556	8569	5554		10666	6620	9742	12630	7651	11192	14477	9099	13245	17010	BTU
2000	78,7	50	1440	2135	2790	1809		3473	2156	3172	4113	2491	3645	4714	2963	4313	5539	Watt
			4914	7284	9521	6171		11851	7355	10824	14034	8501	12436	16086	10110	14716	18900	BTU
2200	86,6	55			3069				2371	3490	4524	2741	4009	5186				Watt
					10473				8091	11907	15437	9351	13679	17694				BTU
2400	94,5	60			3348				2587		4935	2990		5657				Watt
					11425				8826		16840	10201		19303				BTU
2600	102,4	65			3627				2802		5347	3239		6129				Watt
					12377				9562		18244	11051		20912				BTU
2800	110,2	70			3907													Watt
					13330													BTU
3000	118,1	75			4186													Watt
					14282													BTU
Radiator exponent n			1,330	1,327	1,329	1,342	1,334	1,353	1,354	1,342	1,377	1,366	1,349	1,400	1,375	1,360	1,412	

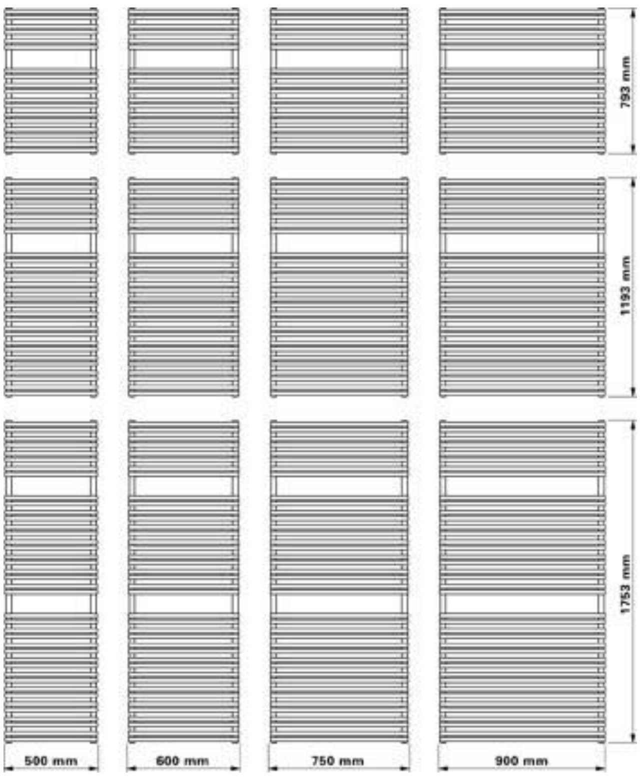
Outputs are calculated using Delta T 60 (90/70/20).

Towel Dryer emitters:

Typical application is bath and toilet. Additional function apart from heating is drying towels.

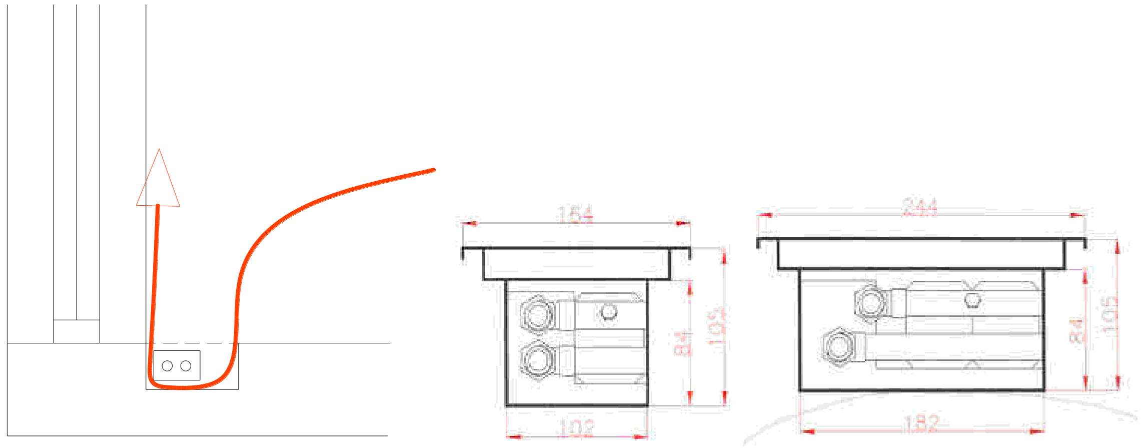


Typical sizes



are quite often assembled with electric heat battery for the time period when the whole area is not heated but the shower and bath are not hot enough.

Floor Convectors



Floor convectors are more like increasing thermal comfort in rooms in a case of large glazed surfaces. Depending on mean temperature different it emits 150-250W/m heat. In the floor it needs ~10cm height.

Surface heating:

Because condensing boilers work more efficiently at lower temperatures, pairing an surface heating system can reduce heating costs. A condensing boiler runs in the more cost-efficient condensing mode at lower temperatures, which saves money. surface heating is also well suited for usage with solar heating and heat pumps.

The system consists of 10 mm to 22 mm o.d. pipes embedded in the floor, ceiling or walls. This has the benefit of reducing flow temperature and improved efficiency of heat production. Heat distribution is uniform, providing a high standard of thermal comfort as heat is emitted from the building fabric. However, thermal response is slow as the fabric takes time to heat up and to lose its heat. Thermostatic control is used to maintain surface temperatures:
Range of surface temperature

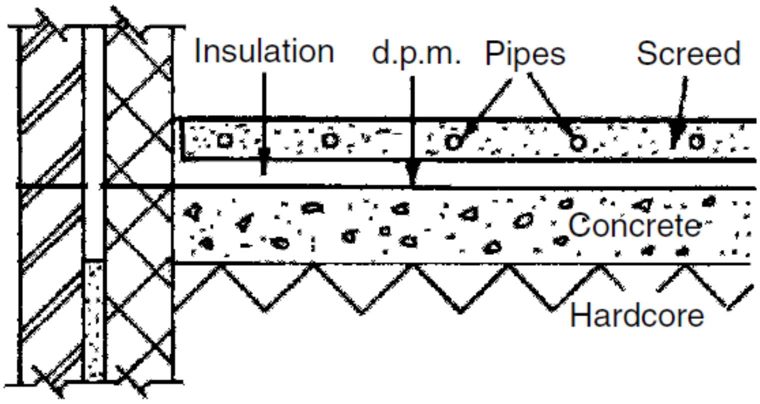
Floors: Occupied area: 28°C, edge: 30°C, bath 32°C
Ceilings 40°C
Walls 40°C
The actual surface temperature very much depends on the covered surface heating area.

Used pipe materials:
Joints on copper pipes must be made by capillary soldered fittings or by bronze welding. Unjointed purpose-made plastic pipes can also be used. Before embedding the pipes they should be hydraulically tested as described on page.

Types of surface heating:

Floor heating:
A viable alternative to conventional radiator style heating systems is under-floor heating. A typical solution consists of small bore pipes, laid in the concrete slab under the floor’s surface. The solution is typically fed by a condensing boiler.

Heating buildings in this way provides a consistent, even heat release from floor level. It provides comfort underfoot and pleasant temperatures. The pipes are hidden, so there are no unsightly radiators. It also uses a lower water temperature to maintain the same room temperature level as radiator systems.



Method of embedding the panels

Current practice is to use jointless plastic pipe in continuous coils. Pipes can be embedded in a 70 mm cement and sand screed (50 mm minimum cover to tube). In suspended timber floors the pipe may be elevated by clipping tracks or brackets with metallic reflective support trays, prior to fixing the chipboard decking.

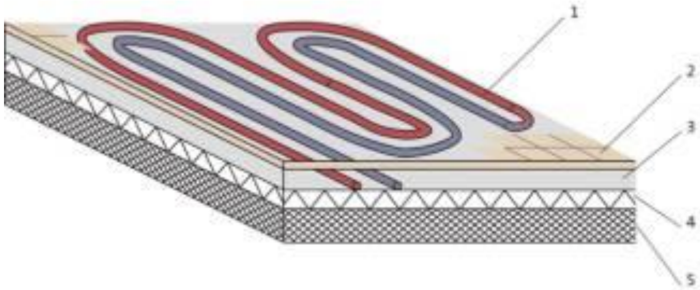
Materials include:
PEX: Cross linked polyethylene.
PP: Co-polymer of polypropylene.
PB: Polybutylene.

These pipes are oxygen permeable, therefore, when specified for underfloor heating, they should include a diffusion barrier.

Extract from performance tables for a design room temperature of 21°C with a blended flow temperature of 50°C:

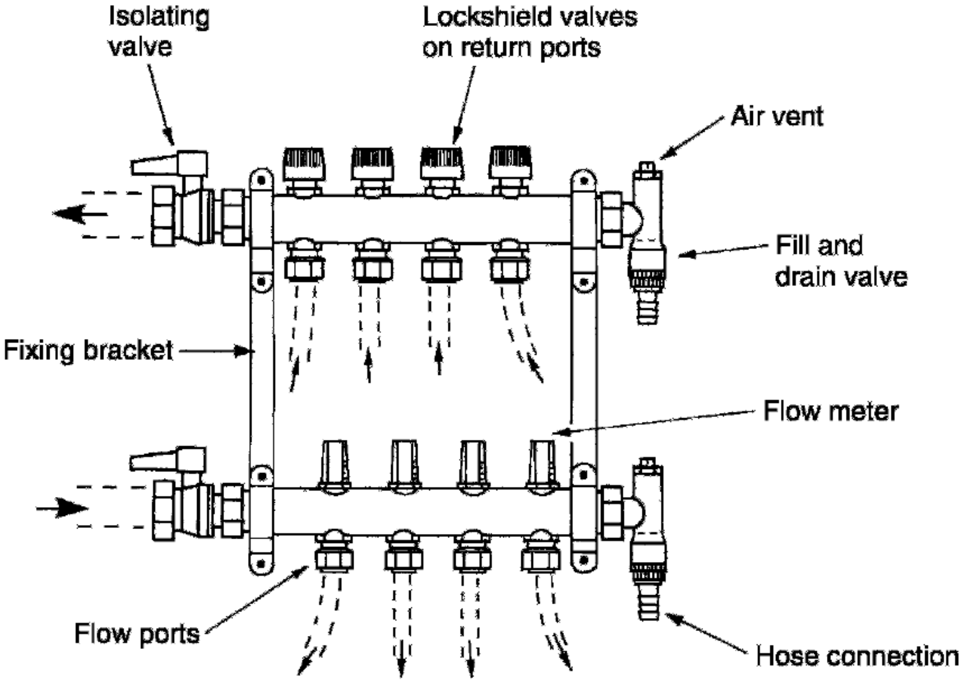
Solid floor – Pipe dia. (mm)	Pipe spacing (mm)	Output (W/m^2)
15	100	82
15	200	67
18	300	55
Suspended floor –		
15	300*	47

For the sake of comfort, the floor's surface temperature should ideally lie between 26-34°C. This is a relatively low flow temperature. The obtainable temperature difference will lie between 5-10°C, which is lower than that of radiator systems (15-20°C). Floor heating systems thus use a higher water flow to achieve the same temperature results.



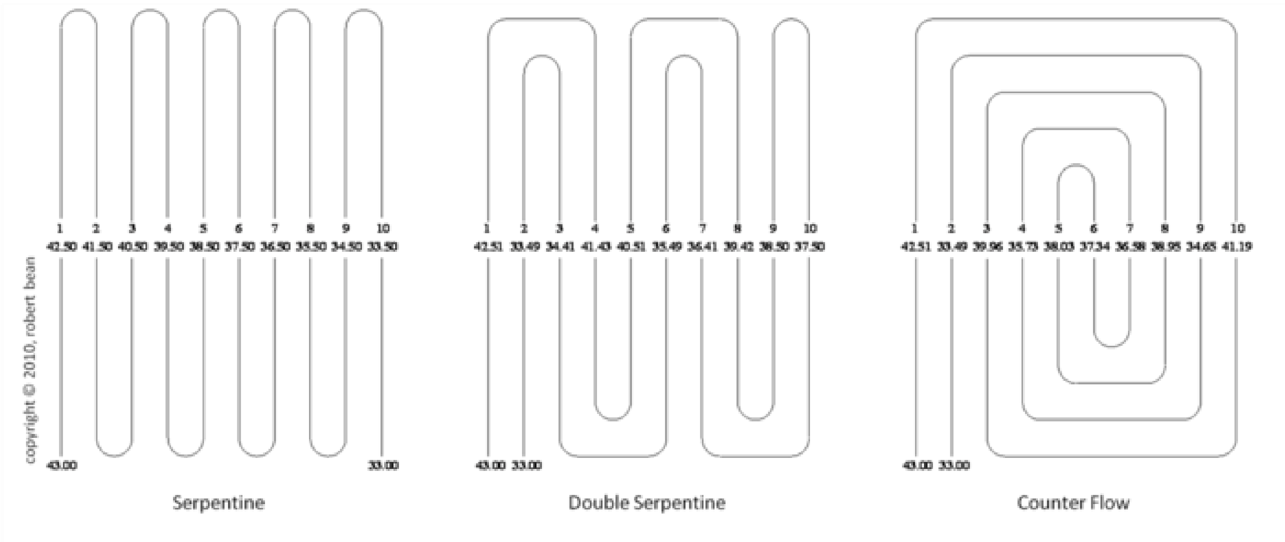
1. Heating pipes
2. Floor
3. Concrete
4. Insulation
5. Concrete slab

Generally distribution network for surface heating consist a manifold. Manifold or header manifolds are discretely located on a wall or within a boxed unit. Manifolds comprise: . Flow port, return ports, drain valve and hose connection (may be used for filling), air ventilation valve, isolating valve to each bank of ports, visual flow meters to each flow port, balancing valve on each return port.

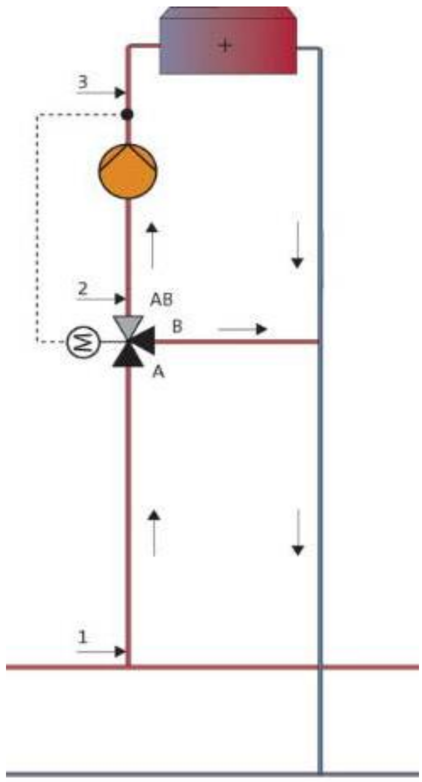


Layer details

The way of laying the pipe has an effect on uniformity of temperature distribution at the surface. The most uniform temperature is given by the counter flow distribution.



Controlling temperature by mixing valve:



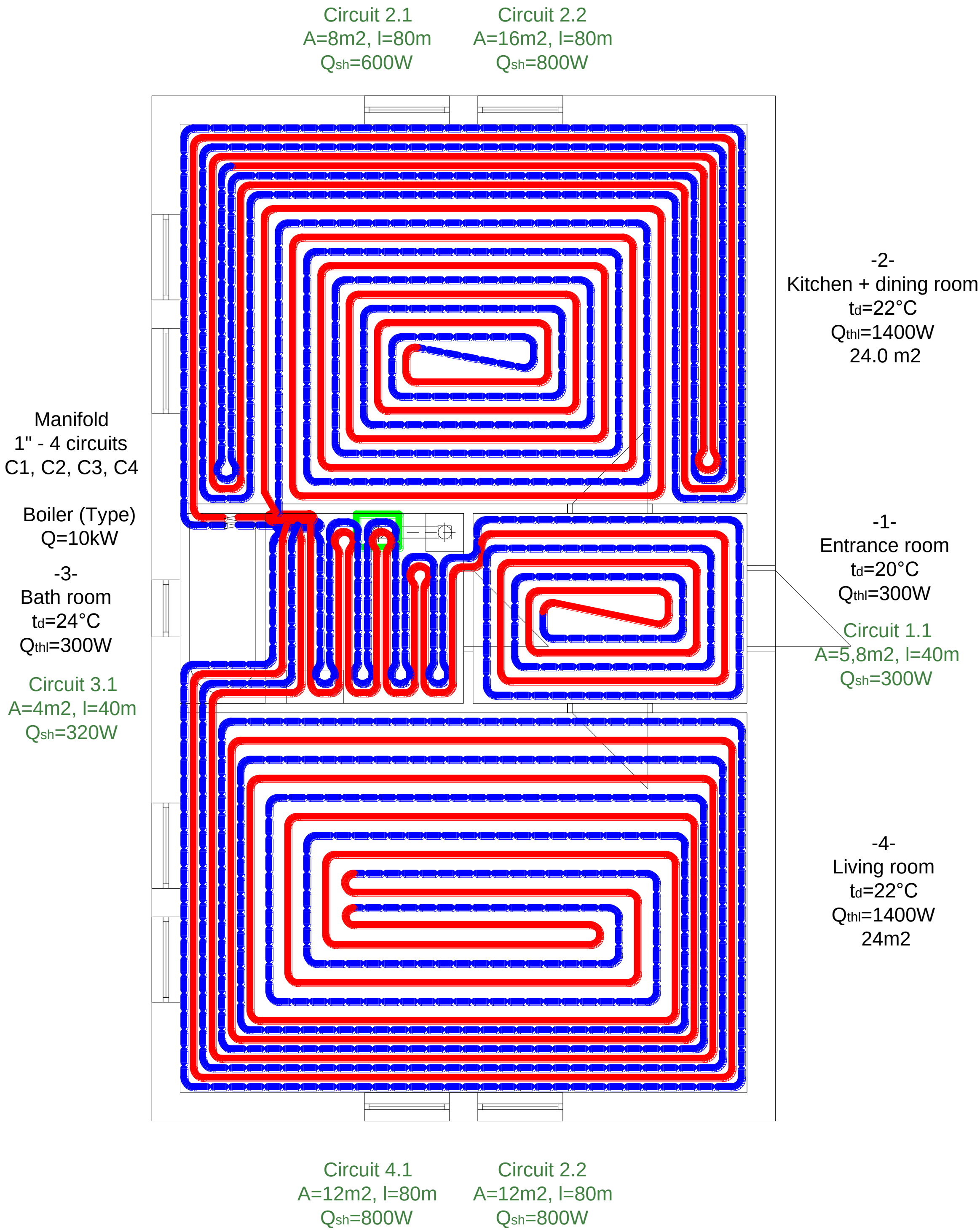
Boiler flow temperature for underfloor heating is about 40°C, whilst that for hot water storage and radiators is about 80°C. Therefore, where the same boiler supplies both hot water storage cylinder and/ or radiators and underfloor heating, a motorised thermostatic mixing valve is required to blend the boiler flow and underfloor heating return water to obtain the optimum flow temperature.

Temperature control is achieved by additional pump and tree way valve. Function:
Secondary side:
The load will normally be an exchanger, where the temperature out of the exchanger is the setpoint. The flow decreases when the valve is closing. The valve can be placed either in the flow pipe or in the return pipe.The pressure lost in the bypass has to be close to the same as the pressure lost in the system. Primary side: The flow is constant, but the differential temperature will change when the valve is adjusting.

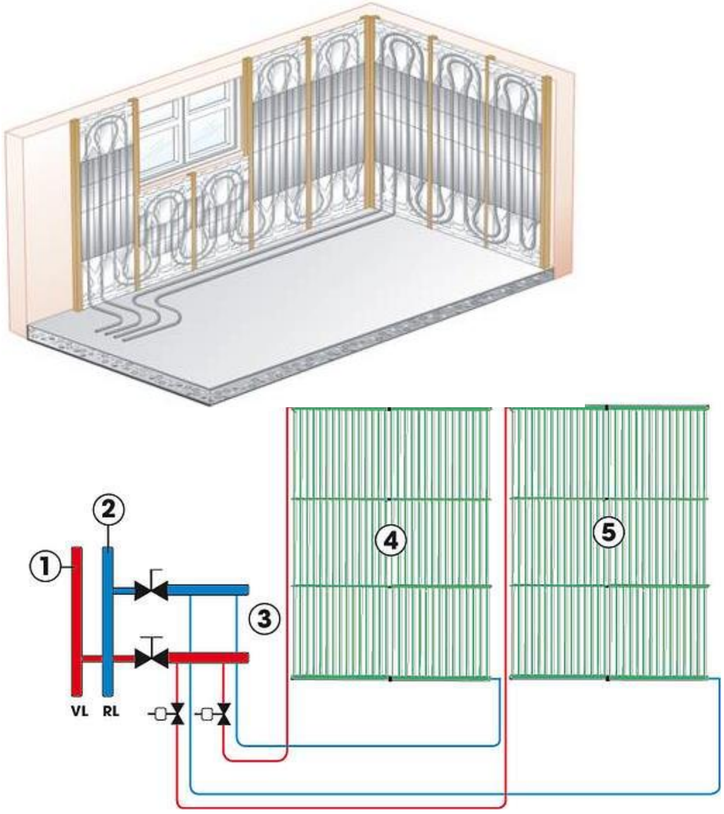
Heat emission:

Heat emission of surface heating depends on the thermal resistance above the pipe (unnecessary heat loss depends on the thermal resistance under the pipe), which is a thickness of the concrete slab and material of the floor tile. Also depends on the flow temperature, length of one circuit and pipe density (distance in-between pipes). In practise by considering the above mentioned dependencies nomograms (sizing diagrams) are frequently used.

Example of construction design


Circuit 2.1
A=8m2, l=80m
Qsh=600W
Circuit 2.2
A=16m2, l=80m
Qsh=800W
-2-
Kitchen + dining room
td=22°C
Qthl=1400W
24.0 m2
Manifold
1" - 4 circuits
C1, C2, C3, C4
Boiler (Type)
Q=10kW
-3-
Bath room
td=24°C
Qthl=300W
Circuit 3.1
A=4m2, l=40m
Qsh=320W
-1-
Entrance room
td=20°C
Qthl=300W
Circuit 1.1
A=5,8m2, l=40m
Qsh=300W
-4-
Living room
td=22°C
Qthl=1400W
24m2
Circuit 4.1
A=12m2, l=80m
Qsh=800W
Circuit 2.2
A=12m2, l=80m
Qsh=800W

Wall heating



Ceiling heating (and cooling)